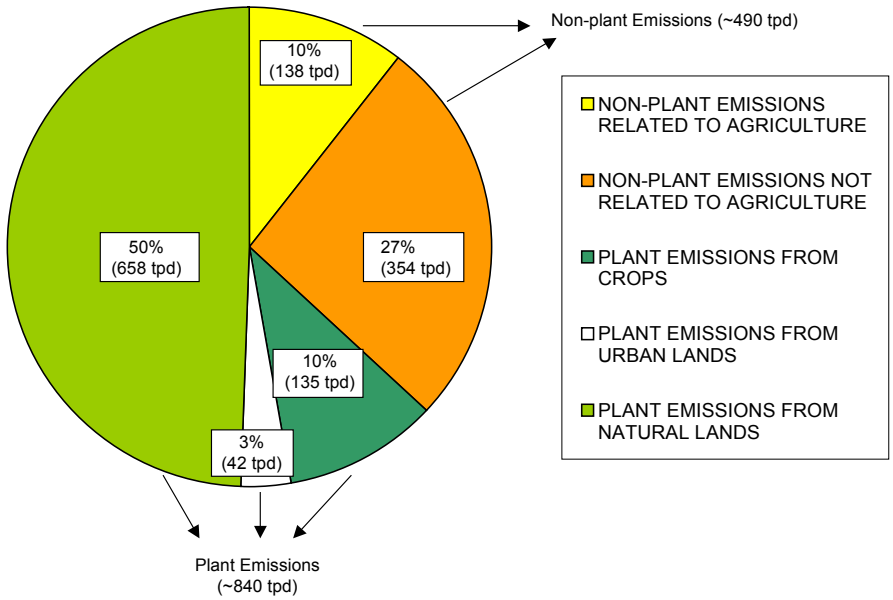
Agricultural Crop Emissions in the San Joaquin Valley

Background

Reactive organic gas (ROG) emissions are estimated for crops, plants in urban areas, and plants in natural areas using a GIS-based model. A GIS-based model allows information such as crop type or plant species to be defined at a high resolution and spatially distributed, even defining the actual location of a field and the type of crop. ROG emissions from plants are a function of the type and quantities of plants, the leaf mass for different plant species, emission factors, temperature, and light conditions. ROG emissions from plants are extremely sensitive to temperature. Crop ROG emission factors for monoterpenes and isoprene used in the GIS-based model are based upon California crop emission measurements reported in the scientific literature. Figure 1 shows the total ROG emissions in the San Joaquin Valley.

On a typical summer day in the San Joaquin Valley Air Basin, ROG emissions from plants total about 840 tons per day, about two-thirds of all ROG emissions,

Figure 1. Summertime 2000 ROG Emissions in the San Joaquin Valley (~1330 tons/day)



of which approximately 15% originate from crops, 5% from plants in urban areas, and 80% from plants in natural areas. Most of the natural emissions are produced in the heavily forested Sierra Nevada Mountain portion of the Air Basin and not on the Valley floor where most of the ozone is formed. The remaining ROG emissions come from a wide variety of sources. About 20% of all ROG emissions (approximately 270 tons per day) come from sources related to agriculture. These sources include plant emissions from crops, livestock waste, pesticides, farm equipment, agricultural burning, and facilities that process

agricultural products. The emissions that are generated on the Valley floor have a much greater impact on ozone formation than biogenic emissions created far from urban areas.

Emissions from Crops

Table 1 below ranks the top fifteen crop types in the San Joaquin Valley based on their daily emissions of ROG. This emission ranking takes into account the total acreage of each crop in the Valley, as well as crop-specific parameters (emission factor, leaf mass) and the effects of temperature. Most crop emissions are monoterpenes, which are moderately reactive. Emission factors are drawn from peer-reviewed scientific literature and represent the best available data.

Table 1
Ranking of Crop Types in the San Joaquin Valley by Daily ROG Emissions for a Typical Summer Day

			Emission Factor ug/g dry leaf weight/hr		ROG Emissions	
Rank	**Crop**	**Acres**	**Monoterpene**	**Isoprene**	**tons/day**	**% total**
1	TOMATOES	225,523	20		85.3	63.2
2	PISTACHIOS	73,856	8.4		22.5	16.7
3	COTTON	880,976	0.7		10.1	7.5
4	ORANGES	170,316	0.9		5.1	3.8
5	FIGS	11,987	0.2	27	3.3	2.4
6	WALNUTS	111,039	1.8		1.9	1.4
7	BELL PEPPERS	6,836	10		1.3	1.0
8	ALFALFA	590,229	0.2		0.9	0.7
9	ALMONDS	413,069	0.05		0.5	0.4
10	LEMONS	7,892	1.5		0.4	0.3
11	CORN	421,887	0.03		0.2	0.1
12	GRAPEFRUIT	3,035	1.5		0.2	0.1
13	OLIVES	20,445	0.3		0.1	0.1
14	PEACHES	51,610	0.1		0.1	0.1
15	NECTARINES	32,780	0.1		0.1	0.0
	ALL OTHER CROPS	2,479,730			3.1	2.3
TOTAL OF ALL CROPS		**5,501,210**			**135.0**	**100.0**

References for Table 1

Benjamin M. T., Sudol M., Bloch L., and Winer A. M. (1996) Low-emitting urban forests: a taxonomic methodology for assigning isoprene and monoterpene emission rates. Atmospheric Environment 30, 1437-1452.

Lamb B., Gay D., Westburg H., and Pierce T. (1993) A biogenic hydrocarbon emission inventory for the U.S. using a simple forest canopy model. Atmospheric Environment 27, 1673-1690.

Winer A. M., Arey J., Atkinson R., Aschmann S. M., Long W. D., Morrison C. L. and Olszyk D. M. (1992) Emission rates of organic compounds from agricultural and natural vegetation found in California's Central Valley. Atmospheric Environment 14, 2647-2659.

These fifteen crop types, which constitute 55% of the agricultural acreage in the Valley, contribute approximately 98% of the 135 tons per day of ROG emitted by crops on a typical summer day. Tomatoes are the most significant ROG emitting crop type due primarily to their relatively high monoterpene emission factor compared to other crops with larger acreages, such as cotton, alfalfa, almonds, and corn. Some of the most common crop types in the Valley, such as grapes, do not appear in this emissions list due to their low monoterpene emission factors. Also, the roughly five million acres of unirrigated rangelands in the SJV emit a total of only one ton per day of ROG emissions.

Table 2 shows that for all crop types, temperature has a dramatic impact on ROG emissions. A rise in temperature from 90 F to 110 F results in a two to three fold increase in ROG emissions from crops. Table 3 shows the county acreage for each of the 15 listed crops.

Table 2
Effect of Temperature on ROG Emissions
from Crops in the San Joaquin Valley

			Emissions (pounds ROG/hour)			
Ranking	**Crop**	**Acres**	**80 F**	**90 F**	**100 F**	**110 F**
1	TOMATOES	225,523	4,068	6,706	11,057	18,230
2	PISTACHIOS	73,856	1,075	1,772	2,922	4,818
3	COTTON	880,976	481	793	1,308	2,157
4	ORANGES	170,316	243	400	659	1,087
5	FIGS	11,987	276	520	785	707
6	WALNUTS	111,039	90	149	246	405
7	BELL PEPPERS	6,836	62	102	168	276
8	ALFALFA	590,229	45	74	123	202
9	ALMONDS	413,069	23	38	63	104
10	LEMONS	7,892	19	31	51	84
11	CORN	421,887	10	16	26	43
12	GRAPEFRUIT	3,035	7	12	20	32
13	OLIVES	20,445	5	9	15	24
14	PEACHES	51,610	4	7	11	19
15	NECTARINES	32,780	3	4	7	12
	ALL OTHER CROPS	2,479,730	104	172	284	668
TOTAL OF ALL CROPS		**5,501,210**	**6,514**	**10,806**	**17,744**	**28,867**

Table 3
County Acreages for the Highest ROG Emitting Crops in the San Joaquin Valley

	Crop Acreages by County							
Crop	Fresno	Kern	Kings	Madera	Merced	San Joaquin	Stanislaus	Tulare
TOMATOES	115,000	7,400	9,969	0	15,600	24,700	19,800	
PISTACHIOS	4,541	29,077	6,916	19,270	4,473	0	0	9,579
COTTON	302,700	215,975	228,865	27,500	66,891	0	0	83,392
ORANGES	26,252	35,484	0	3,830	0	0	0	104,751
FIGS	0	0	0	9,550	2,437	0	0	0
WALNUTS	3,122	1,455	6,401	1,210	5,151	40,100	24,400	29,200
BELL PEPPERS	2,380	2,200	0	0	406	1,850	0	0
ALFALFA	71,400	129,000	53,710	36,500	75,177	57,600	40,100	92,888
ALMONDS	57,350	82,572	1,796	47,600	77,314	41,800	88,900	15,737
LEMONS	830	3,388	0	0	0	0	0	3,674
CORN	30,170	570	42,991	17,100	73,007	92,560	54,700	110,790
GRAPEFRUIT	1,063	0	0	0	0	0	0	1,972
OLIVES	1,230	730	0	1,780	0	0	0	16,705
PEACHES	13,953	1,622	3,647	2,080	5,427	2,800	8,150	13,931
NECTARINES	13,784	1,267	1,537	610	164	0	0	14,995

Estimates of Ozone Removal by Crops in the San Joaquin Valley Using Published Ozone Removal Rates

Background

One method of estimating ozone removal for crops is by multiplying published ozone removal rates for each crop by the crop acreage. Using this approach, ozone removal due to crops is about 650 tons per day.

California ozone removal rates are available for four crop types and rangeland. The rates were computed based on data from the report, *Study Demonstrates Ozone Uptake by SJV Crops*[1]. These removal rates were assigned to the over 100 crop types grown in the SJV. In many cases, there were not good fits between the crops and available removal rates, so best guess assignments were used. Attachment 1 summarizes the crop assignments and the total acreage of each crop in the SJV.

Fortunately, due to the relative similarity of the removal rates (except for rangeland), the error in specific assignments is not significant. Table 4 below summarizes the removal rates used in this analysis.

Table 4
Crop and Rangeland Removal Rates

Crop Type	Ozone Removal Rate (lbs/acre/day)
Rangeland	0.06
Grapes	0.22
Cotton	0.27
Orchards	0.21
Corn	0.26

Crop Acreage Estimates

Crop acreage was estimated based on year 2000 acreage data from the California Department of Food and Agriculture (CDFA). These data are compiled by county agricultural commissioners, and are the official California data of record for crop production, which are provided to the U.S. Government for compiling national statistics. Because this is an annual value (not just summer) and may include acreage from double cropping, the estimated acreage estimate may be somewhat high. The total estimated acreage of croplands in the San Joaquin Valley is about 5 million acres, and there are roughly 5 million acres of rangeland.

Table 5 summarizes the ozone removed by all crops and rangeland within the San Joaquin Valley. Based on this analysis, approximately 802 tons per day of ozone could be removed by crops and rangelands. If unirrigated rangelands are excluded, the reduction is about 650 tons per day.

Table 5
Estimated Crop and Rangeland Ozone Removal in the SJV by County

	Acres	**Average Removal Rate** (lb/acre/day)	**Ozone Removed** (tons per day)
Fresno	2,098,819	0.17	174
Kern	2,848,088	0.11	162
Kings	711,735	0.20	71
Madera	661,110	0.14	46
Merced	1,130,793	0.16	88
San Joaquin	695,505	0.20	71
Stanislaus	802,655	0.17	66
Tulare	1,569,890	0.16	124
Total	**10,518,595**	**0.15**	**802**
Total without Rangeland	**5,501,210**	**0.24**	**650**

The table also provides a computed average removal rate for each county based on dividing the number of acres by the total removal. The variations between counties are primarily due to the amount of unirrigated rangeland, which has a much lower ozone removal rate than the other vegetation.

Reference

[1]Grantz, D. A., Pederson, J. et al. (1994) Study Demonstrates Ozone Uptake by SJV Crops. California Agriculture, Vol. 48 No. 4, pp. 9-12.

Attachment 1

Summary of Crop Acreages and Ozone Removal Factors for the San Joaquin Valley

Crop (Sorted by Removal Category and Acres)	**Acres**	**Removal Category**	**Ozone Deposition Rate** (lbs/acre/day)	**Ozone Deposition** (tons/day)
CORN GRAIN	92,950	Corn	0.26	12.08
ASPARAGUS UNSPECIFIED	26,190	Corn	0.26	3.40
CORN SWEET ALL	10,816	Corn	0.26	1.41
COTTON LINT UPLAND	570,026	Cotton	0.27	76.95
HAY ALFALFA	556,375	Cotton	0.27	75.11
PASTURE IRRIGATED	321,341	Cotton	0.27	43.38
CORN SILAGE	318,121	Cotton	0.27	42.95
SILAGE	220,437	Cotton	0.27	29.76
COTTON LINT PIMA	216,559	Cotton	0.27	29.24
TOMATOES PROCESSING	192,469	Cotton	0.27	25.98
FIELD CROPS UNSPECIFIED	103,942	Cotton	0.27	14.03
COTTON LINT UNSPECIFIED	94,391	Cotton	0.27	12.74
VEGETABLES UNSPECIFIED	68,281	Cotton	0.27	9.22
HAY GRAIN	61,184	Cotton	0.27	8.26
SUGAR BEETS	54,155	Cotton	0.27	7.31
COTTON SEED PLANTING	44,347	Cotton	0.27	5.99
HAY OTHER UNSPECIFIED	42,197	Cotton	0.27	5.70
MELONS CANTALOUPE	41,546	Cotton	0.27	5.61
BEANS DRY EDIBLE UNSPEC.	39,499	Cotton	0.27	5.33
SEED ALFALFA	33,854	Cotton	0.27	4.57
TOMATOES FRESH MARKET	32,884	Cotton	0.27	4.44
ONIONS	25,050	Cotton	0.27	3.38
POTATOES IRISH ALL	23,600	Cotton	0.27	3.19
HAY GREEN CHOP	22,600	Cotton	0.27	3.05
GARLIC ALL	22,590	Cotton	0.27	3.05
LETTUCE HEAD	20,610	Cotton	0.27	2.78
RICE MILLING	18,806	Cotton	0.27	2.54
SAFFLOWER	18,203	Cotton	0.27	2.46
BEANS BLACKEYE (PEAS)	12,500	Cotton	0.27	1.69
FIELD CROPS SEED MISC.	11,307	Cotton	0.27	1.53
BROCCOLI UNSPECIFIED	11,260	Cotton	0.27	1.52
POTATOES SWEET	10,386	Cotton	0.27	1.40
BEANS LIMA LG. DRY	9,677	Cotton	0.27	1.31
HAY SUDAN	9,204	Cotton	0.27	1.24
BEANS LIMA UNSPECIFIED	9,100	Cotton	0.27	1.23
MELONS WATERMELON	7,907	Cotton	0.27	1.07
PEPPERS BELL	6,836	Cotton	0.27	0.92
SEED VEG & VINECROP	5,227	Cotton	0.27	0.71
MELONS UNSPECIFIED	4,920	Cotton	0.27	0.66
BEANS KIDNEY RED	4,900	Cotton	0.27	0.66

Crop (Sorted by Removal Category and Acres)	**Acres**	**Removal Category**	**Ozone Deposition Rate** (lbs/acre/day)	**Ozone Deposition** (tons/day)
LETTUCE LEAF	4,800	Cotton	0.27	0.65
PUMPKINS	4,550	Cotton	0.27	0.61
MELONS HONEYDEW	4,460	Cotton	0.27	0.60
BEANS LIMA BABY DRY	4,190	Cotton	0.27	0.57
PEAS GREEN PROCESSING	3,157	Cotton	0.27	0.43
SPINACH UNSPECIFIED	2,870	Cotton	0.27	0.39
BEANS SEED	2,758	Cotton	0.27	0.37
CUCUMBERS	2,601	Cotton	0.27	0.35
BEANS LIMA GREEN	2,309	Cotton	0.27	0.31
CAULIFLOWER UNSPECIFIED	2,290	Cotton	0.27	0.31
SEED OTHER (NO FLOWERS)	2,080	Cotton	0.27	0.28
BROCCOLI FRESH MARKET	1,356	Cotton	0.27	0.18
VEGETABLES ORIENTAL ALL	1,350	Cotton	0.27	0.18
LETTUCE BULK SALAD PRODS.	1,170	Cotton	0.27	0.16
SQUASH	1,040	Cotton	0.27	0.14
BEANS SNAP FRESH MARKET	1,036	Cotton	0.27	0.14
EGGPLANT ALL	910	Cotton	0.27	0.12
BROCCOLI PROCESSING	766	Cotton	0.27	0.10
CAULIFLOWER FRESH MARKET	373	Cotton	0.27	0.05
BEANS GARBANZO	322	Cotton	0.27	0.04
TOMATOES CHERRY	170	Cotton	0.27	0.02
COTTONSEED		Cotton	0.27	0.00
GRAPES WINE	304,214	Grapes	0.22	33.46
GRAPES RAISIN	194,030	Grapes	0.22	21.34
GRAPES TABLE	87,377	Grapes	0.22	9.61
GRAPES UNSPECIFIED	13,800	Grapes	0.22	1.52
BERRIES STRAWBERRIES	1,047	Grapes	0.22	0.12
ALMONDS ALL	413,069	Orchards	0.21	43.37
ORANGES NAVEL	121,476	Orchards	0.21	12.75
WALNUTS ENGLISH	111,039	Orchards	0.21	11.66
PISTACHIOS	73,856	Orchards	0.21	7.75
ORANGES VALENCIA	45,010	Orchards	0.21	4.73
PLUMS	37,656	Orchards	0.21	3.95
NECTARINES	32,780	Orchards	0.21	3.44
PEACHES FREESTONE	32,736	Orchards	0.21	3.44
OLIVES	20,445	Orchards	0.21	2.15
APPLES ALL	18,448	Orchards	0.21	1.94
CHERRIES SWEET	18,360	Orchards	0.21	1.93
PEACHES CLINGSTONE	17,252	Orchards	0.21	1.81
APRICOTS ALL	15,319	Orchards	0.21	1.61
PLUMS DRIED	14,534	Orchards	0.21	1.53
FRUITS & NUTS UNSPECIFIED	14,470	Orchards	0.21	1.52
FIGS DRIED	11,987	Orchards	0.21	1.26
LEMONS ALL	7,892	Orchards	0.21	0.83
POMEGRANATES	4,205	Orchards	0.21	0.44

Crop (Sorted by Removal Category and Acres)	**Acres**	**Removal Category**	**Ozone Deposition Rate** (lbs/acre/day)	**Ozone Deposition** (tons/day)
ORANGES UNSPECIFIED	3,830	Orchards	0.21	0.40
GRAPEFRUIT ALL	3,035	Orchards	0.21	0.32
TANGERINES & MANDARINS	2,604	Orchards	0.21	0.27
KIWIFRUIT	2,552	Orchards	0.21	0.27
PEARS UNSPECIFIED	2,371	Orchards	0.21	0.25
PEACHES UNSPECIFIED	1,622	Orchards	0.21	0.17
TANGELOS	1,470	Orchards	0.21	0.15
PERSIMMONS	1,303	Orchards	0.21	0.14
CITRUS UNSPECIFIED	1,205	Orchards	0.21	0.13
PECANS	898	Orchards	0.21	0.09
AVOCADOS ALL	646	Orchards	0.21	0.07
QUINCE	213	Orchards	0.21	0.02
CITRUS BY-PRODUCTS MISC.		Orchards	0.21	0.00
BIOMASS ORCHARD		Orchards	0.21	0.00
ALMOND HULLS		Orchards	0.21	0.00
WHEAT ALL	346,821	Rangeland	0.06	10.40
PASTURE FORAGE MISC.	45,596	Rangeland	0.06	1.37
BARLEY UNSPECIFIED	24,008	Rangeland	0.06	0.72
WHEAT SEED	4,191	Rangeland	0.06	0.13
BARLEY FEED	4,100	Rangeland	0.06	0.12
OATS GRAIN	2,727	Rangeland	0.06	0.08
SORGHUM GRAIN	211	Rangeland	0.06	0.01
STRAW		Rangeland	0.06	0.00
Subtotal for crops	**5,501,210**	**Weighted Average**	**0.24**	**650**
PASTURE RANGE	5,017,385	Rangeland	0.06	150
Total	**10,518,595**	**Weighted Average**	**0.15**	**800**